Development of a Global Hydrographic Climatology with High Quality Arctic Data

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LONG-TERM GOALS

Our long-term goal is to better represent the Arctic Ocean in numerical models. In order to validate these models, we need high quality gridded fields of observed quantities such as ocean temperature and salinity. Both the historical mean and the historical variance are required. We then need to discover where and when the models diverge from the observations. Armed with this knowledge, we can proceed to make improvements that will assist the Navy with their forecasting mission.

OBJECTIVES

Our specific objective in this project is to assist in the development and validation of Polar Ice Prediction System 3.0, the next generation Navy operational polar model. Specifically, we have developed a gridded oceanic data set that we call the Polar science center Hydrographic Climatology, or PHC. It consists of global temperature and salinity fields using new Russian and Western arctic data that can be used for model initialization, restoring, and validation. We are extending this data set by filling data gaps, creating variance fields, and using it to validate a suite of numerical models.

APPROACH

Our approach is to merge two data sets: (1) The Arctic Ocean Atlas (AOA) produced by the Environmental Working Group (*EWG*, 1997, 1998) in which formerly classified Russian and Western data have been gridded into fields for the Arctic Ocean and Nordic Seas, and (2) the World Ocean Atlas, 1998 version (WOA98; *Antonov et al.*, 1998; *Boyer et al*., 1998) produced by the National Oceanographic Data Center (NODC) under the leadership of S. Levitus, which includes data from many sources into a global product. NODC does not have access to the original Russian data that are included in the AOA, and thus the Arctic Ocean fields in WOA98 are not as reliable.

We merged AOA and WOA98 mean temperature and salinity fields using optimal interpolation. The AOA data were assigned lower error in the Arctic regions than the WOA data. The opposite was true in the Nordic Seas, as we found that the WOA reproduced the strong exchanges of Atlantic and Arctic waters more accurately than the AOA. Our result is a global product that includes a state-of-the-art representation of the Arctic Ocean (Figure 1). It provides the first comprehensive view of waters as they move from the North Pacific, through Bering Strait into the Arctic Ocean, and then out the Canadian and Eurasian straits into the Northwest and Northeast Atlantic Ocean. The product is

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14. ABSTRACT
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interpolated onto the exact same grid as the WOA98 product and in the exact same format, making it easy for current WOA users to use our new PHC product.

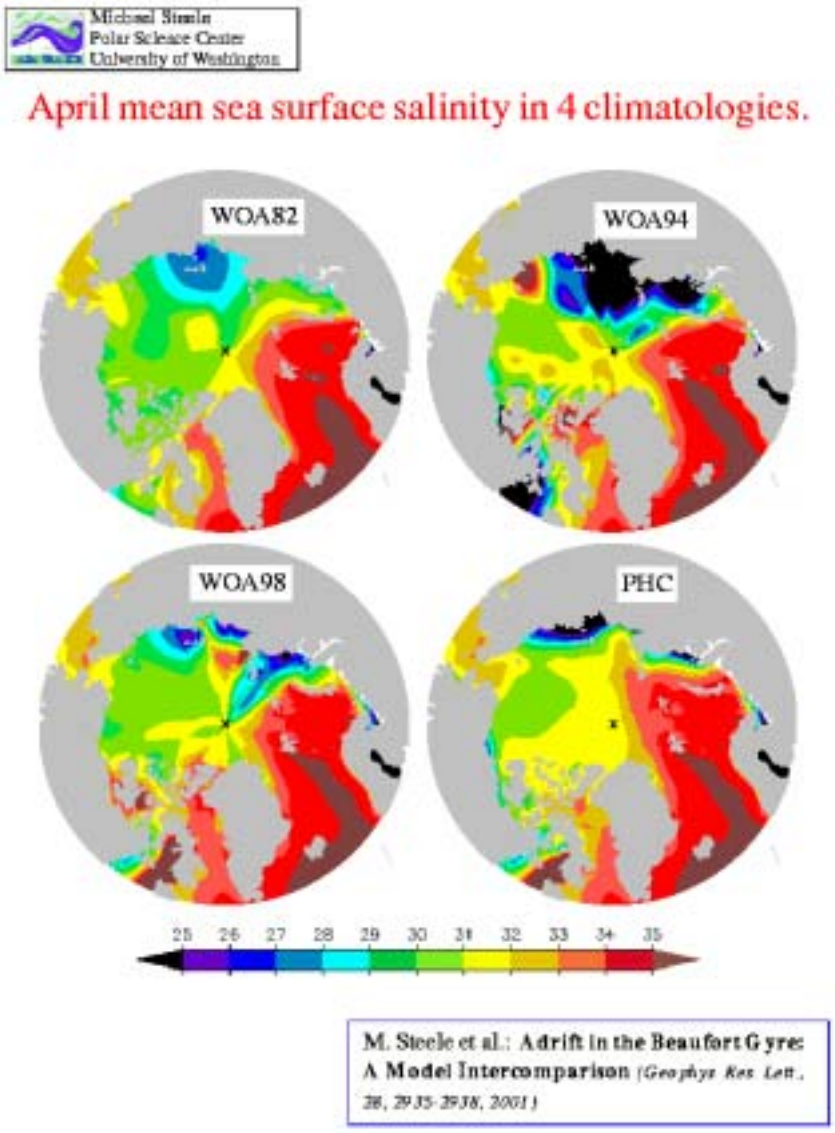

Figure 1. April mean sea surface salinity (SSS) in four climatologies. The World Ocean Atlas (WOA) was produced in 1982, 1994, and 1998 (e.g., Boyer et al., 1998). It contains relatively few observations in the wintertime Arctic Ocean interior, and thus has a warm and fresh (i.e., summertime) bias in this region. Also, WOA extrapolates lower latitude data towards the North Pole, but not across it, leading to alternating fresh and salty "lobes" centered at the pole. The Polar science center Hydrographic Climatology (PHC) combines WOA98 and previously unavailable Russian and western data (EWG, 1997 and 1998) to produce fields with a reduced summer bias and no polar lobing. The March mean for WOA82 is shown here since April means were not provided. The North Pole is marked with an "x."

The existing PHC product contains some data "holes" that are not filled by either AOA or WOA. An example is eastern Canadian waters (e.g., Hudson Bay) during winter, where PHC fields (like the WOA fields) are generally too warm. Some of these regions have recently been shown to be sites where PIPS2.0 sea ice forecasts consistently underestimate sea ice coverage. We are tackling this problem by acquiring more data, some of which require further quality control.

Comparison of mean model output with mean PHC fields gives an indication of model bias. We are proceeding with these comparisons here at Polar Science Center, and also cooperatively with other institutions as part of the Arctic Ocean Model Intercomparison Project (AOMIP).

We expect that such biases will occur in any model-data comparison. The question is, how significant are these biases? For example, if in a particular region the number of observations are few and/or if the observed variance is high, then a bias may not be statistically significant, i.e., it may not be cause for alarm. We have begun to explore this issue by examining variance fields produced in the two data sets (AOA and WOA) in preparation for a merging project to be completed in the next two years.

M. Steele is responsible for guiding this research; W. Ermold is the programmer who runs the merging and graphics analysis software.

WORK COMPLETED

The PHC web site was updated to reflect changes made in the previous year. PHC now provides high quality fields of global mean temperature and salinity for Navy model initialization, climate restoring, and validation. Several dozen other modeling centers are also using this product. A paper was published that describes this work (*Steele et al*., 2001a). In addition, we have presented this material at several national and international meetings and workshops.

We used PHC in the validation of late winter sea surface salinity (SSS) as simulated by a variety of coupled sea ice – ocean numerical models (Figure 2). One of these was a prototype version of PIPS3.0. We found many differences between the models and also relative to the PHC observations. In particular, we found a general model bias towards overly salty conditions within the Beaufort Gyre. The cause is still under investigation. Our results were presented in a publication (*Steele et al.*, 2001b).

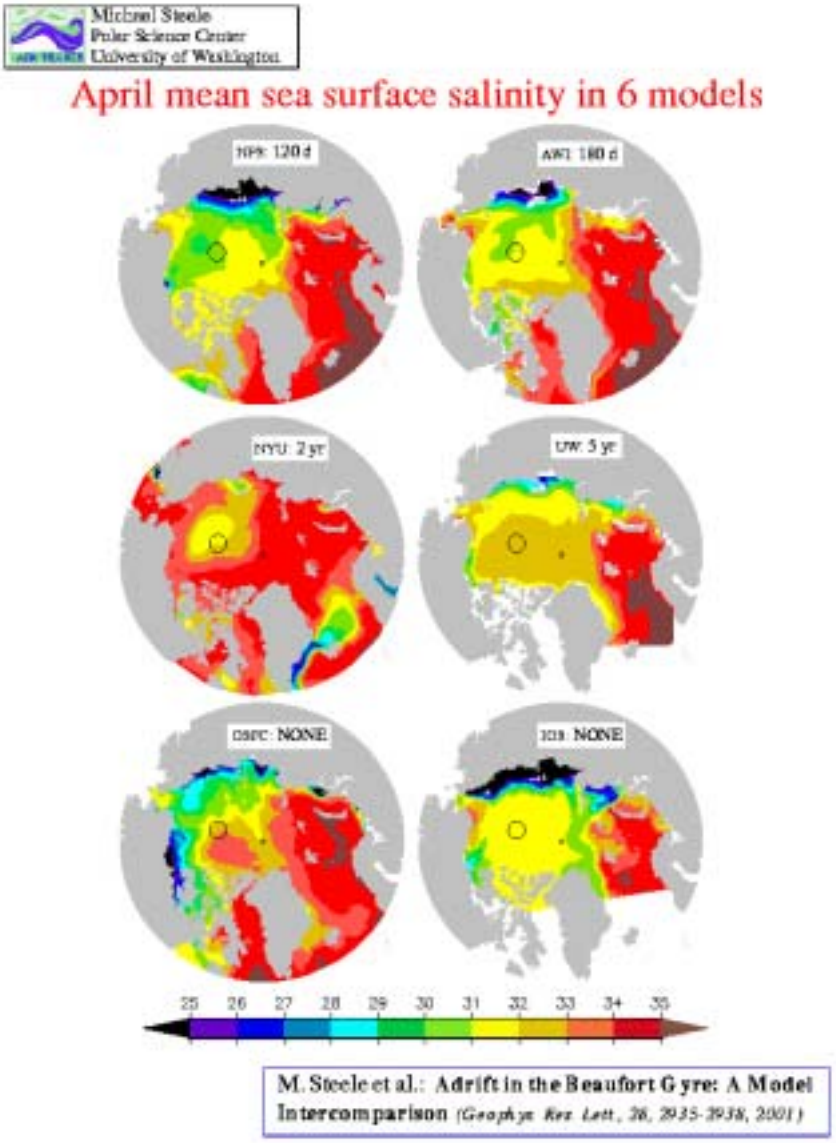

Figure 2. April mean sea surface salinity (SSS) and its restoring time constant in six model simulations. Longer restoring times indicate weaker restoring, i.e., less artificial constraining of the model solution back towards climatology. Model output from NPS (Naval Postgraduate School; restoring time τ = 120 days), AWI (Alfred Wegener Institute; τ = 180 days), UW (University of Washington; τ = 5 years), and GSFC (Goddard Space Flight Center; $\tau = \infty$) is averaged over years 1979-1988, while output from NYU (New York University; τ = 2 years) and IOS (Institute of Ocean Sciences; $\tau = \infty$) uses climatological average forcing. SSS within the 200 km radius circles (centered at 160°W, 80°N in the Beaufort Gyre) generally increases as the restoring time constant increases, indicating a community-wide salty bias in the simulation of this region.

In order to “plug the holes” in PHC, we have acquired data from the Bedford Institute of Oceanography in Nova Scotia, Canada. Much of these data did not find their way into either the AOA or WOA databases. Their coverage is sparse in winter, and their quality is variable. However, our preliminary analysis indicates that with judicious selection of interpolation parameters, there are enough good observations to significantly improve PHC fields in this region (i.e., cool them down during winter) and thus improve PIPS ice pack forecasts. Our work is proceeding on this front.

I reviewed a manuscript written by R. Preller et al. that describes PIPS and the development of the new PIPS3.0, to be published in the Oceanography Society magazine in late 2001.

RESULTS

We have learned that it is possible to create a gridded global mean ocean climatology that for the first time contains a high quality Arctic Ocean. The data set has been downloaded by over 40 different polar researchers and is in use by Navy PIPS3.0 developers in Monterey, California.

We used PHC to discover that most ice-ocean models contain a salty bias in their simulation of the waters north of Alaska and Canada (i.e., the Beaufort Gyre). This model intercomparison and validation is a very powerful exercise, in that it shows the common errors of many model simulations.

IMPACT/APPLICATION

With better observational data sets in hand, we have begun to better document where PIPS and other models contain errors. This will help to determine where model improvements are best made. Our study of SSS errors indicates that decreasing the artificial “climate restoring” term in PIPS may lead to significant long-term biases, unless simultaneous improvements are made in model physics, numerics, or forcing.

TRANSITIONS

Navy PIPS modelers have been successfully using PHC in model initialization and for climate restoring.

RELATED PROJECTS

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PUBLICATIONS

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Steele, M., W. Ermold, S. Häkkinen, D. Holland, G. Holloway, M. Karcher, F. Kauker, W. Maslowski, N. Steiner, and J. Zhang, Adrift in the Beaufort Gyre: A model intercomparison, *Geophys. Res. Lett.*, *28*, 2935-2938, 2001.